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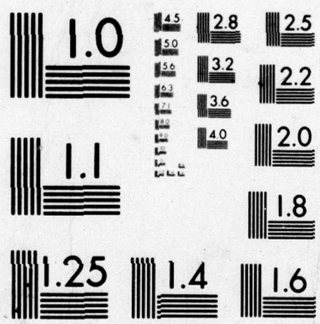

MICROCOPY RESOLUTION TEST CHART

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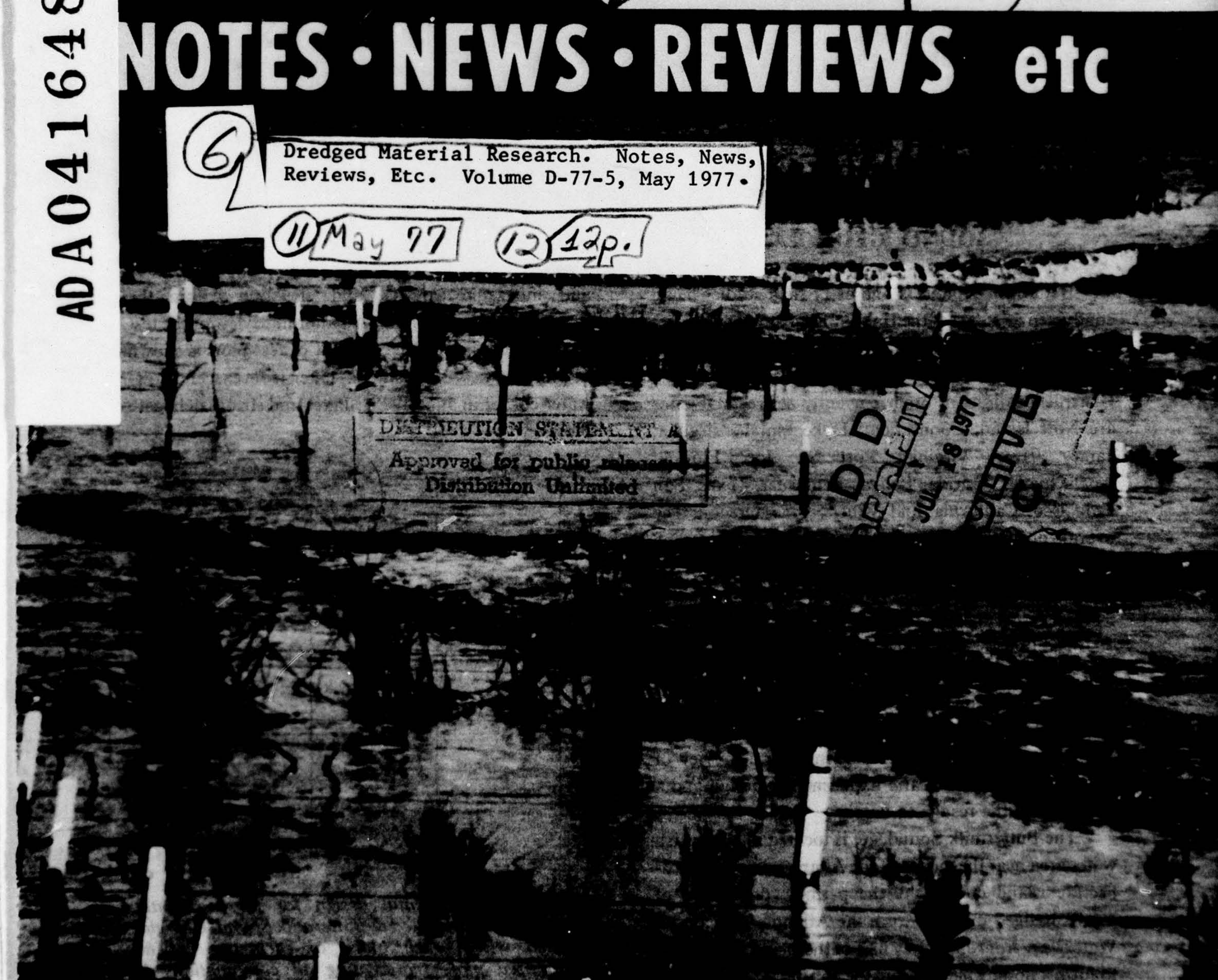
DREDGED MATERIAL RESEARCH

U. S. ARMY CORPS OF ENGINEERS
[INFOR]MATION EXCHANGE BULLETIN

Vol D-77-5
May 1977

NOTES • NEWS • REVIEWS etc



A once sandy and barren portion of a disposal site in Buttermilk Sound, Georgia, has been used to test particular design aspects of salt marsh habitat development by the Dredged Material Research Program (DMRP). A portion of the 720 1.5- by 3.0-m plots established in 1975 are shown in the above photo taken in April 1976. Planning, site preparation, and monitoring activities associated with marsh plant survival and productivity studies are discussed in the following article along with preliminary findings and trends.

UPDATE: MARSH HABITAT DEVELOPMENT AT BUTTERMILK SOUND, GEORGIA

Buttermilk Sound is one of 11 field studies being conducted as a part of the Habitat Development Project (HDP) of the Dredged Material Research Program in coastal and riverine areas throughout the United States. General locations of other currently active HDP sites are Nott Island, Connecticut; Dyke Marsh, Virginia; James River, Virginia; Port St. Joe, Florida; Apalachicola, Florida; Bolivar Peninsula, Texas; San Francisco, California; and Miller Sands, Oregon. The overall objective of the HDP is to test concepts and methods of habitat development on dredged material and to evaluate habitat development as an alternative method of dredged material disposal.

The first report on the Buttermilk Sound Habitat Development Site appeared in this Information Exchange Bulletin in December 1975. Since that time research has progressed sufficiently that general trends can be seen in the data. The following is a brief review of the site characteristics and experimental design and a summary of the results to date.

The Buttermilk Sound site is located in a brackish water area near the mouth of the Altamaha River on a 2-hectare island created by the periodic deposition of sandy dredged material from the Atlantic Intracoastal Waterway. Approximately half of the island was graded to form a sloping plain within the intertidal zone. A total of 720 1.5- by 3.0-m plots with a 0.7-m buffer zone between each plot was established on the plain according to a factorial experiment where the experimental variables (factors) were plant species (seven species plus a control), propagule (seed or sprigs), fertilizer treatment (control plus two levels of an organic and inorganic carrier), and elevation within the intertidal zone (Figure 1). A panoramic view of the test site after grading and laying out of test plots is shown above. The view of the site was taken from east end, low-water corner in June 1975. Stakes and strings delineate plots.

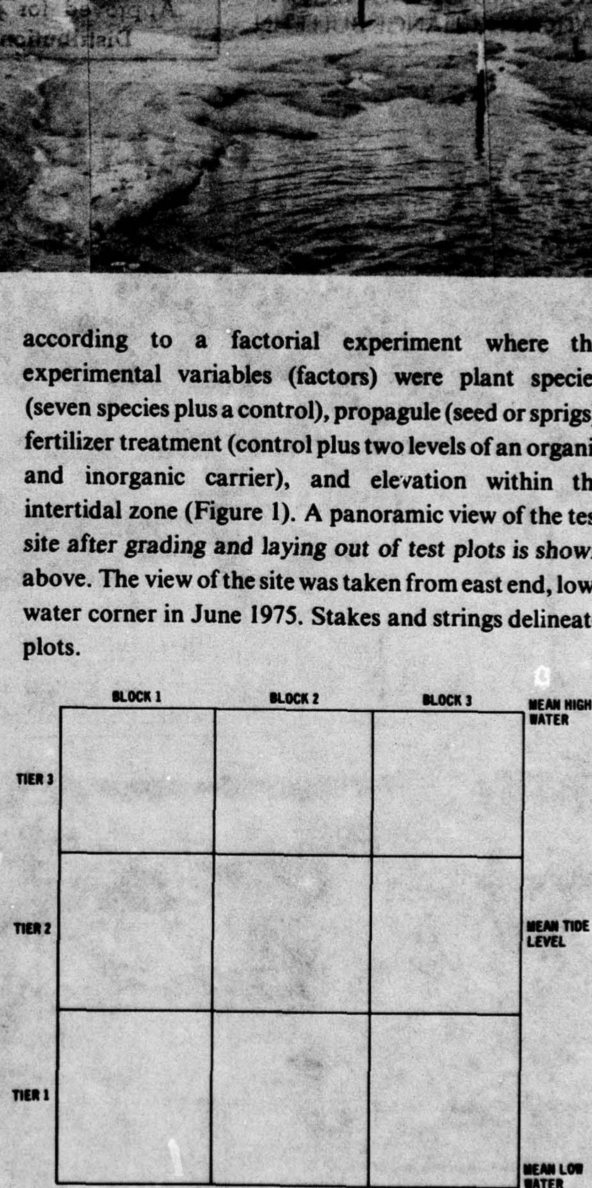
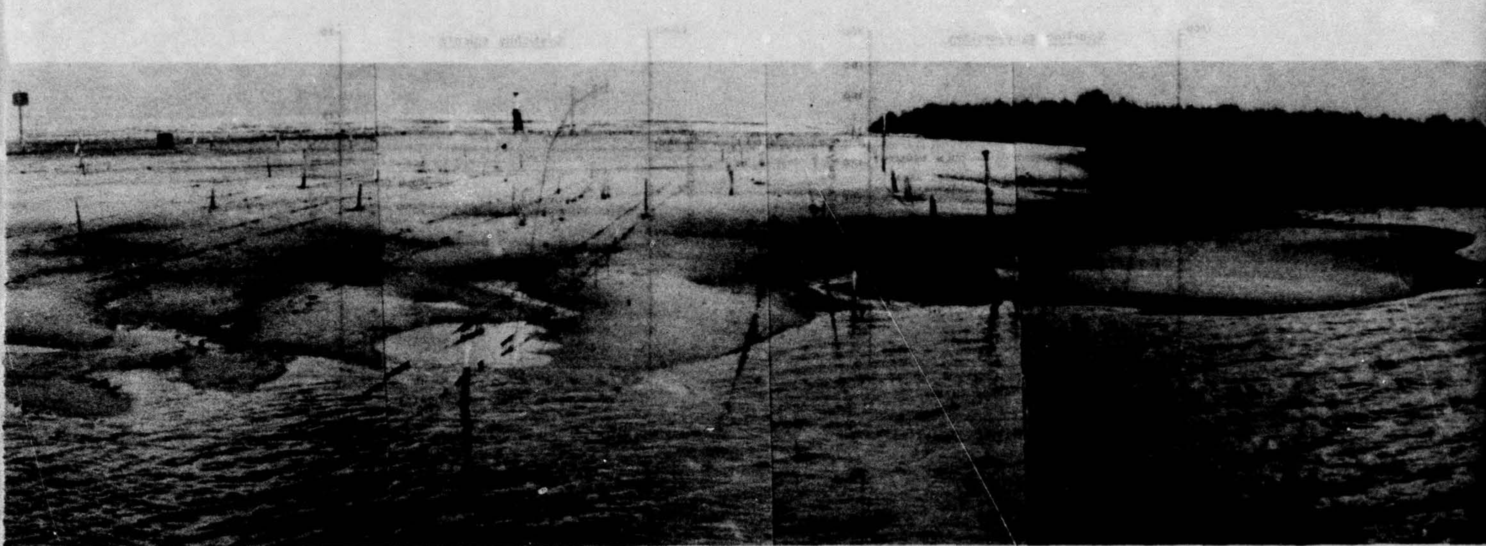


Figure 1. Experimental design for marsh habitat development site located at Buttermilk Sound, Georgia. Situated within each block of each tier are 80 randomized plots representing all combinations of fertilizer treatment (5), propagule (2), and species (8). Each plot is 1.5- by 3.0-m in size and is surrounded by a 0.7-m buffer zone.



The plots were laid out in a modified version of a randomized complete block design. The experimental treatment "elevation" could not be randomly located over the experimental area, thus the intertidal zone was broken into three tiers and all treatment combinations for a given tier and block were randomly located within each tier times block combination (Figure 1).

Plots established by sprigging were planted in June 1975; the seeded plots were established in April 1976. The plant species being studied are *Spartina alterniflora, S. patens, S. Cynosuroides, Juncus roemerianus, Distichlis spicata, Borrichia frutescens,* and *Iva frutescens*. Fertilizer was applied at the time of planting. Fertilizer treatments were: none, 122 and 244 g/m² of a 10:10:10 inorganic fertilizer, and 33 and 66 g/m² of a 16:4:8 organic fertilizer (i.e., tankage plus inorganic nutrients).

Plant establishment and growth and the evolution of the substrate are being intensively monitored. Additionally, data on water quality, aquatic biota in the adjacent waters, and wildlife utilization of the site and surrounding area are being recorded.

ELEVATION

Plant response to elevation within the intertidal zone has been dramatic. Plants propagated by sprigs became established within the upper two thirds of the intertidal zone; however, there is a strong zonation by species within the intertidal zone. Figure 2 shows the

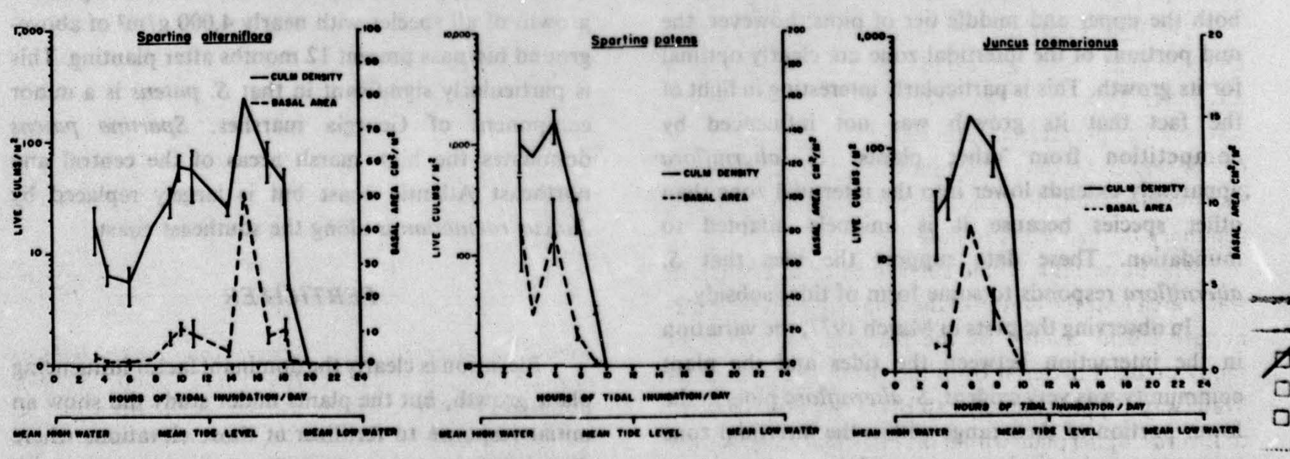


Figure 2. Growth of plant species as a function of hours of tidal inundation per day (Continued)

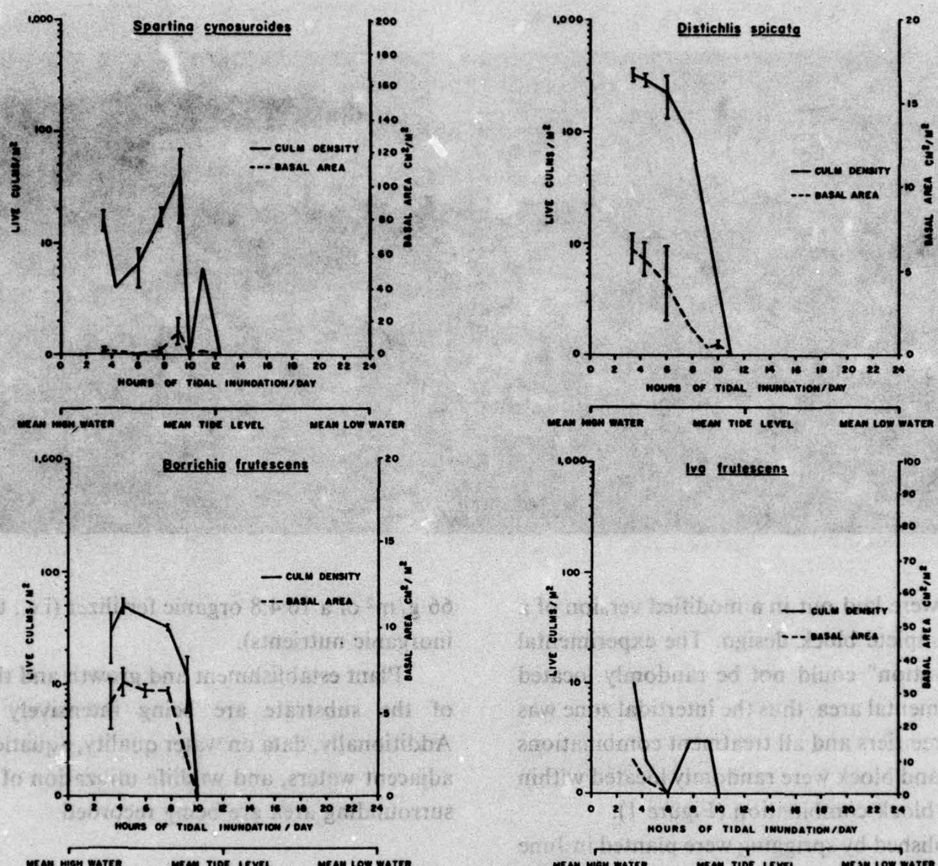


Figure 2. (Continued)

growth of all seven species of plants as of April 1976 as indicated by the number of culms and basal area as a function of the hours of tidal inundation. Figure 3 shows the response of the species to environmental conditions.

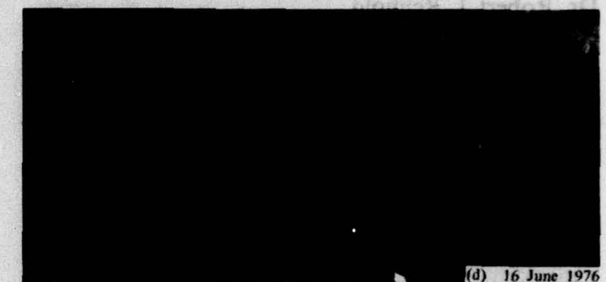
Spartina alterniflora **has been successful over the greatest range within the intertidal zone, growing in both the upper and middle tier of plots; however, the mid portions of the intertidal zone are clearly optimal for its growth. This is particularly interesting in light of the fact that its growth was not influenced by competition from other plants. *S. alterniflora* apparently extends lower into the intertidal zone than other species because it is uniquely adapted to inundation. These data support the idea that *S. alterniflora* responds to some form of tidal subsidy.**

In observing the plots in March 1977, the variation in the interaction between the tides and the plant community was very evident. *S. alterniflora* plots in the lower portion of their range within the intertidal zone were green and actively growing and there was a virtual absence of dead material, the latter having been harvested by the tides. At higher elevations a great deal of dead material remained. Possibly the reduced harvesting of the previous season's growth at the higher elevations is a factor in the reduced growth of *S. alterniflora* at higher elevations.

In the upper tier of plots, *S. patens* had the greatest growth of all species with nearly 4,000 g/m² of above-ground biomass present 12 months after planting. This is particularly significant in that *S. patens* is a minor component of Georgia marshes. *Spartina patens* dominates the high marsh areas of the central and northeast Atlantic coast but is largely replaced by *Juncus roemerianus* along the southeast coast.

FERTILIZER

Elevation is clearly the dominant factor influencing plant growth, but the plants under study did show an initial response to fertilizer at those elevations where they were not severely stressed by the degree of inundation. Although fertilizer was not a critical factor



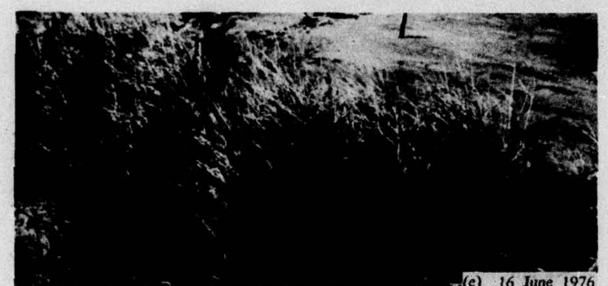


Figure 3. Predictably, the various marsh species tested demonstrated different responses to environmental conditions. Of these species only Spartina alterniflora *(a) was successful at lower intertidal elevations;* Iva frutescens *(b),* Borrichia frutescens *(c),* Distichlis spicata, Spartina cynosuroides, *and* Juncus roemerianus *(d) present a varied picture of success, but all survived only at the upper elevations.* Spartina patens *(e), again a species confined to higher tidal elevations, was the most productive of the species tested, demonstrating a dramatic increase in biomass and calm density*

in the establishment of plants at Buttermilk Sound, the fact that the plants did respond suggests that fertilizer would be advantageous in those locations where quick initial growth might make the difference between success and failure.

PROPAGULE

Plant establishment by seeding has generally proven to be difficult as well as unpredictable. However, in the upper third of the intertidal zone, good results were obtained by seeding with two species, *Distichlis spicata* and *Borrichia frutescens.* Failure of a given species to be successfully established by seed must be evaluated in light of the fact that at present little is known about the proper storage and germination requirements for most of the species used. Dr. James D. Maguire, a seed physiologist at Washington State University, Pullman, Washington, is presently investigating the storage and germination requirements of the seed of all the species of marsh plants that have been used at the various marsh habitat development sites.

SUBSTRATE

The evolution of the new marsh substrate and the biological community is being monitored. Fine-grained sediments are slowly accumulating on the site and this should result in an increase in the fertility of the substrate. The level of plant nutrients (nitrogen, phosphorus, and potassium) and the change in cation exchange capacity and organic carbon over time in each plot are being monitored. Barring unanticipated toxic effects, it is reasonable to assume that the soil fertility and productivity of the new marsh will increase for an undeterminable, but finite, period of time.

The research at Buttermilk Sound will be reported in a site report that will be published in the spring of 1978. Additionally, several synthesis reports will be

produced that summarize the research at all the HDP field sites by subject area. The Buttermilk Sound study is part of Task 4A (Marsh Development) of the HDP. Dr. Hanley K. Smith is Project Manager. Site planning and management activities are the responsibility of Dr. J. Scott Boyce, Environmental Resources Division. The research is being conducted by the Marine Resources Extension Center, University of Georgia, Brunswick, Georgia, under the direction of Dr. Robert J. Reimold.

SELECTIVE PARTITIONING OF SEDIMENTS TO EVALUATE MOBILITY OF CHEMICAL CONSTITUENTS

INTRODUCTION

When sediments are agitated by dredging or subsequently resuspended in the water by discharge operations, there is a possibility that some chemicals in the sediment could be released into the water column. In order to assess the impact of dredged material discharge upon water quality, specifically as reflected by the elutriate test (a short-term leach of dredged material with dredging site water at a sediment-to-water ratio approximating the slurry formed during hydraulic dredging), and to elucidate the form and species of contaminants in sediments, a selective extraction procedure for sediments was developed.

Work Unit 1E04 of the DMRP presents the results of a study conducted to determine the partitioning of various elements within dredged material and their effect on water quality. The study was conducted by Messrs. J. M. Brannon and I. Smith, Ms. J. R. Rose, and Drs. R. M. Engler and P. G. Hunt, Ecosystem Processes Research Branch, EEL.

The selective extraction procedure is applicable to marine and freshwater environments, both aerobic and anaerobic. It minimizes disruption or perturbation of the dredged material during sampling, shipping, and handling, thus reducing change in phases or fraction differentiation or change in the chemical nature of constituents, due to factors such as air oxidation, drying and grinding, or freezing.

A sediment can conceptually be partitioned into phases or fractions where chemical constituents can be extracted as a function of the analytical procedure and the physicochemical nature of the specific constituent. Quantitative knowledge of the selective distribution of chemicals in dredged material can aid in determining the relative availability of these chemicals to the water column during dredging operations, their availability to biological communities, and their availability to enter into chemical reactions.

EXPERIMENTAL METHODS

Sediments sampled for the study came from freshwater, estuarine, and saltwater environments in Ashtabula, Ohio; Mobile Bay, Alabama; and Bridgeport, Connecticut, respectively. They represented a wide range of contaminant concentrations, organic and inorganic carbon contents, and particle-size distributions (Table 1). Separation of the sediments into several phases was accomplished under controlled laboratory conditions.

Table 1

AVERAGE PHYSICAL AND CHEMICAL SEDIMENT CHARACTERISTICS

Parameter	Location: Mobile Bay	Ashtabula	Bridgeport
Particle-size distribution, percent:			
<2 μm	52.70	36.00	38.30
2-50 μm	32.50	62.70	58.20
>50 μm	14.80	1.30	3.50
Cation exchange capacity, meq/100 g	46.30	16.90	23.90
Total organic carbon (C), percent	2.03	2.42	2.69
Total inorganic C, percent	0.07	0.56	2.19
Total sulfides, μg/g	903.00	240.00	2,680.00
Total nitrogen (N), μg/g	1,900.00	1,390.00	2,680.00
Total metals, μg/g:			
Fe	42,900.00	42,400.00	43,600.00
Mn	746.00	642.00	531.00
Cu	37.48	40.87	1,117.00
N	156.00	213.00	203.00
Cd	3.62	4.14	17.60
Zn	234.00	444.00	1,067.00
As	4.08	6.50	6.90
Hg	0.52	0.61	1.12

The functionally defined phases of dredged material studied in this selective extraction procedure were those dissolved in interstitial water, adsorbed on sediment material (exchangeable), occluded or coprecipitated with manganese and iron oxide and hydroxide phases (easily and moderately reducible

phases), bound with organic matter and sulfides (organic + sulfide phase), and bound in the crystalline mineral lattice (residual phase) (Figure 1). Sediment was also subjected to the standard elutriate test to evaluate the correlation of the partitioned chemicals with the elutriate.

RESULTS

Nitrogen and Phosphorus in Sediments and in the Elutriate

Ammonium-N and orthophosphate were found in high concentrations in the interstitial water of the majority of sediments studied. Exchangeable ammonium-N concentrations were high in all the sediments. Ammonium-N in the interstitial water could be immediately available to the water column upon disposal of dredged material. The exchangeable ammonium-N would be more slowly released than interstitial water ammonium-N, but would be expected to desorb to some extent into the disposal site water.

Sediments from all sampling areas released high concentrations of ammonium-N during the elutriate test. Ammonium-N concentration in the standard elutriate was directly related to sediment total Kjeldahl nitrogen (organic + NH_4^+-N) concentration and exchangeable phase ammonium-N concentration and inversely related to the clay fraction.

Orthophosphate release in the elutriate test was mainly dependent upon the iron chemistry of the sediments, for a large portion of the oxides and hydroxides. Orthophosphate release in the elutriate test was directly related to its concentration in the interstitial water and inversely related to iron concentration in the interstitial water and exchangeable phases.

Heavy Metal Selective Extraction and Elutriate Test Results

The selective extraction scheme showed good mass balance. Precision was also good as indicated by the low variation between replicate extractions for most metals. Selective extraction has shown itself to be a useful tool for evaluating the ability of contaminants associated with various sediment phases to influence contaminant concentration in the elutriate test.

Iron. Sediment iron was found primarily in the residual and moderately reducible phases (citrate-dithionite extractable). Interstitial water and exchangeable phase iron were present in large amounts in sediments from Ashtabula and Mobile Bay. The precipitation of iron oxides and hydroxides during dredging operations will affect water quality because iron oxides and hydroxides are efficient scavengers of trace metals and orthophosphate. Sediments low in interstitial water and exchangeable iron released greater amounts of trace metals and orthophosphate into the

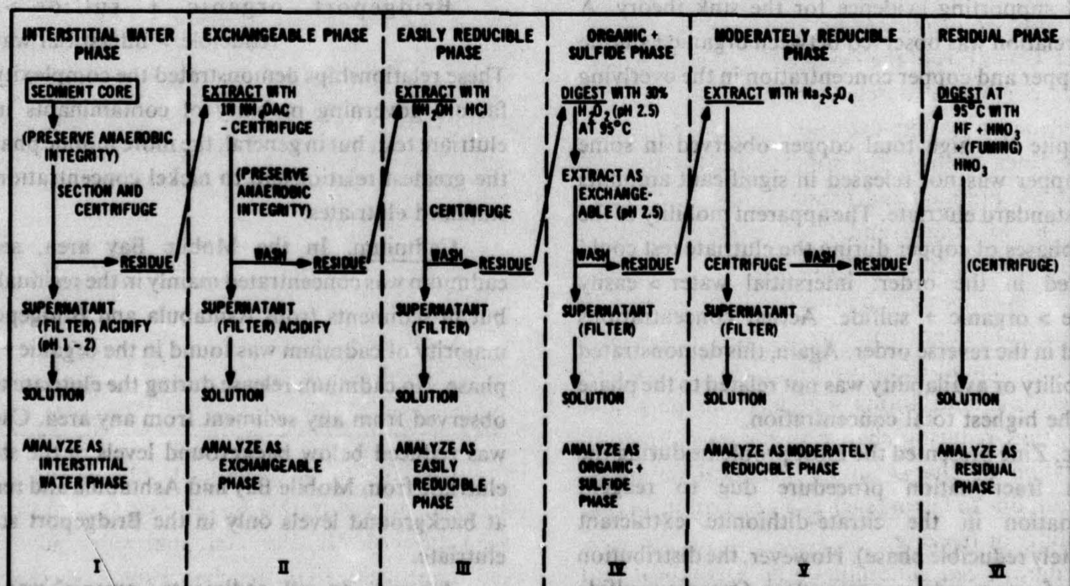


Figure 1. Selective extraction scheme for sediment characterization

standard elutriate than did sediments high in reduced iron concentration.

Manganese. Manganese showed a more variable distribution pattern than most other metals, especially in the case of easily reducible phase manganese (hydroxylomine hydrochloride extractable). In general, manganese concentrations were highest in the organic + sulfide and residual phases of the sediments. Exchangeable phase manganese was correlated with interstitial water and easily reducible phase manganese, suggesting that all three phases were in equilibrium.

Manganese was released in large amounts into the standard elutriate in all areas. Manganese release into the standard elutriate was found to be correlated with the available forms of manganese. The mobility of the various forms of manganese into the standard elutriate could be ranked in the order: interstitial water > exchangeable > easily reducible (even though actual concentration increased in the reverse order). This demonstrated that mobility into the standard elutriate was not related to total concentration but to the physicochemical form of the manganese.

Copper. Copper was found mainly in the residual and organic + sulfide phases of the sediments. The organic + sulfide phase increased in concentration as the total copper concentration of the sediment increased. This may indicate that the organic + sulfide phase acts as a sediment sink for copper. The Bridgeport location provided supporting evidence for the sink theory. A high correlation was observed between organic + sulfide phase copper and copper concentration in the overlying water.

Despite the high total copper observed in some areas, copper was not released in significant amounts into the standard elutriate. The apparent mobility of the various phases of copper during the elutriate test could be ranked in the order: interstitial water > easily reducible > organic + sulfide. Actual concentrations increased in the reverse order. Again, this demonstrated that mobility or availability was not related to the phase having the highest total concentration.

Zinc. Zinc presented the most problems during the sediment fractionation procedure due to reagent contamination in the citrate-dithionite extractant (moderately reducible phase). However, the distribution patterns of zinc in sedimens were clear. Organic + sulfide phase zinc was predominant in all locations with the other major reservoirs consisting of either the residual, easily reducible, or moderately reducible phases.

Zinc concentrations were high in the standard elutriates of sediments from Ashtabula and Bridgeport. These results were apparently due to oxygen depletion in the site water during the elutriate test procedure. High zinc concentrations in the standard elutriates of sediments from Ashtabula and Bridgeport were not seen by other workers in other studies who controlled the dissolved oxygen status of the site water during the elutriate test procedure. The sediment phases that correlated with changes in the standard elutriate concentrations were organic + sulfide phase and easily reducible phase zinc.

Nickel. Sediment nickel was associated primarily with the residual phase in all locations. Organic + sulfide phase nickel was generally of secondary importance and was correlated with the total organic carbon content of the sediments. However, moderately reducible phase nickel was more important than the organic + sulfide phase in Ashtabula sediments.

Nickel was not released in high amounts in the standard elutriate of sediments from any area. Nickel concentration in the standard elutriate was related to nickel concentration in different phases in each area, listed below in order of decreasing mobility for each area:

Mobile Bay—easily reducible

Ashtabula—organic + sulfide

Bridgeport—organic + sulfide > easily reducible > interstitial water

These relationships demonstrated the complexity of the factors governing mobility of contaminants into the elutriate test, but in general, the more mobile phases had the greatest relationship to nickel concentration in the standard elutriates.

Cadmium. In the Mobile Bay area, sediment cadmium was concentrated mainly in the residual phase, but in sediments from Ashtabula and Bridgeport, the majority of cadmium was found in the organic + sulfide phase. No cadmium release during the elutriate test was observed from any sediment from any area. Cadmium was reduced below background levels in the standard elutriate from Mobile Bay and Ashtabula and remained at background levels only in the Bridgeport standard elutriate.

Arsenic. In all sediments, arsenic was found associated with the iron oxide fraction. Arsenic from this fraction showed no mobility during the elutriate

test. Release of arsenic into the standard elutriate was correlated with exchangeable phase arsenic in Ashtabula dredged material, which was the only location where exchangeable phase arsenic was found.

CONCLUSIONS

Elemental partitioning of constituents in sediments has shown the concentrations of trace metals and nutrients in the standard elutriate to be statistically correlated in the majority of cases with their respective concentrations in the interstitial water, exchangeable, and easily reducible phases. The metal or nutrient concentrations in the standard elutriate, therefore, represent the sediment phases thought to be the most mobile and biologically available in the aquatic environment.

No relationship existed between trace metal concentrations in the standard elutriate and total metal concentrations in the sediment. This held true even though some sediments were apparently highly contaminated with some trace metals with respect to total metal concentrations. This suggested that sediments can be a stable sink or repository for some contaminants.

Trace metals extracted in the moderately reducible phase and bound in mineral lattices were not related to trace metal concentration in the standard elutriate. This occurred despite the fact that the majority of sediment arsenic, nickel, and, in some cases, iron and copper were extracted in the moderately reducible and residual phases.

The concentration of reduced iron in the interstitial water and exchangeable phases had a significant inhibitory effect upon the amount of orthophosphate and trace metals released into the standard elutriate. It is anticipated that the same effect would occur in the water column during aquatic disposal.

Zinc, manganese, and ammonia were the only constituents found in the standard elutriate that exceeded the EPA water-quality standards for aquatic life. However, the concentration of any constituent in the standard elutriate does not reflect the dilution that occurs at the dredging and disposal sites.

RECOMMENDATIONS

The elutriate test reflects the more mobile contaminants in sediments and should continue to be used as a criterion for evaluating the short-term effects of open-water disposal of dredged material.

Dissolved oxygen concentrations in the site water during the elutriate test affect the test results. The oxygen content of the elutriate water during the test should be standardized to reflect the oxygenated conditions that usually prevail at dredging and open-water disposal sites.

The elutriate test and other extractants that remove the more mobile sediment phases should be used to assist in evaluating the long-term mass release of contaminants from sediments following aquatic disposal.

When investigating the effect of dredged material disposal on water quality, sediment chemical extractants should be selected that remove mobile sediment phases. Elements bound in immobile phases are unlikely to be chemically or biologically active. In addition to the extractants used in this study, an additional extractant is needed to evaluate the concentration of complexed cations in sediments.

A wide range of chemical extractants and sediments should be used when evaluating the mobility of sediment constituents into the standard elutriate. Ammonium-N and manganese released into the standard elutriate should be thoroughly investigated since high concentrations of both were found in the standard elutriate. Extracting solutions should also be tested for low levels of metals before being used. Low metal levels in the extractants can mask low-level release from the sediments.

This study was conducted as part of DMRP Task 1E, Pollution Status of Dredged Material, Environmental Impacts and Criteria Development Project, Dr. Robert M. Engler, Manager. The report was published as Technical Report D-76-7 and is now available.

NEW LITERATURE

Stickney, R. R. and Perlmutter, D., "Impact of Intracoastal Waterway Maintenance Dredging on a Mud Bottom Benthos Community," *Biological Conservation*, Vol. 7, No. 3, Apr 1976, pp 211-226.

The effects of hydraulic dredging on the benthic infauna of a mud bottom area were investigated in the Atlantic Intracoastal Waterway in Georgia. Complete

displacement of the benthic community was caused by dredging; however, the community began to recover within a month following the cessation of dredging. Within 2 months the diversity and species composition of the dredged channel were similar to that of a control area and little change in sediment composition resulted. Thus, no apparent limitation was imposed on the normal benthic population by habitat alteration. Recolonization was too rapid to have been caused by the settling of immature or larval stages from the water column alone. Bank slumping and migration of adult forms have been postulated as other means of recolonization.

Salem, A. M., *Behavior of Dredged Material in Diked Containment Areas*, Ph. D. dissertation, 1975, Northwestern University, Evanston, Illinois.

The behavioral characteristics of hydraulically placed maintenance dredgings were investigated during an extensive 4-year field and laboratory experimental program. The field work, which took place primarily at 4 disposal areas near Toledo, Ohio, consisted of (a) periodic vane shear strength determination, (b) obtaining undisturbed tube samples for subsequent laboratory tests, and (c) the measurement of in-situ permeability values. One of the field sites was instrumented with settlement plates and piezometers before and during the disposal process, and time-dependent settlements and pore water pressures were monitored during the entire 2-year history of this site. The laboratory testing program included the evaluation of time-dependent (a) volume changes by means of slurry consolidation, conventional consolidation, and long-term secondary compression tests, (b) strength determinations by use of a miniature vane, fall cone, and unconfined compression tests, and (c) various classification tests. Based on an extensive series of classification tests, it was found that the characteristics of the dredged materials deposited in each of the 4 sites were essentially the same, thereby enabling data from the different sites to be synthesized and interpreted as representative of one large site spanning a time period of almost a decade.

Data from about a dozen slurry consolidation tests and more than 60 conventional consolidation tests were used to develop convenient empirical relationships among the compression index, coefficient of consolidation, coefficient of volume compressibility, coefficient of permeability, consolidation pressure, void ratio, and index properties of these materials. Two long-term slurry consolidation tests and 8 long-term conventional consolidation tests were conducted to study the secondary compression-log time response, which exhibits a consistent, but unusual, pattern wherein the rate of secondary compression, after remaining constant with log time for a considerable period of time, increases and forms a second s-shaped curve similar to that normally associated with primary consolidation. Secondary compressions were found to be very significant, often comprising more than one-half of the total settlement; although results from the slurry consolidation tests yielded lower proportions of secondary to total compressions, the total compression per unit height of specimen was nearly the same for both tests. The parameters which characterize the secondary and total compressions, including the coefficient of secondary compression, were correlated with the index properties and consolidation pressure. A combination of data from several types of laboratory and field tests indicates that the coefficient of permeability decreases from about 10^{-4} to 10^{-9} cm/sec as the void ratio decreases from approximately 10 to 1.

Due to the manner of placement, the coarse materials settle near the inflow pipe while the fines accumulate in the vicinity of the outflow weir; grain size analyses show that the percent clay increases from virtually none at the discharge pipe to about 40 percent near the outflow weir, and similar results were found for silt. A synthesis of shear strength data from 4 different sites, together with the deposition histories of these sites and the basic assumption that the materials in each site are essentially similar, allowed the development of a fairly comprehensive relationship for shear strength as a function of both time and space for a hypothetical, geometrically similar, site over a period of about 10 years. Various empirical relationships were established to provide guidance in estimating the strength of similar dredgings. The observed settlements at several locations in the instrumented landfill were found to agree reasonably well with settlements predicted from a mathematical model that accounts for both consolidation and desiccation of the materials, as well as impeded bottom drainage and a nonhomogeneous distribution of mechanical properties in the vertical direction. The average dry density increased about 4 percent per year and the average shear strength increased about 3.5 kN/m^2 (0.5 psi) per year for at least the first 8 years after deposition of the dredgings. Unless steps are taken to accelerate the dewatering of such landfills, their relatively low bearing capacity, as well as the associated settlements, limit to large extent the use of these sites for purposes other than wildlife refuges, parks, recreational areas, parking lots, and access roads to buildings that are supported on appropriate foundations which extend below the deposited dredged materials.

Author's Abstract

Wakeman, Thomas, et al., "Effects of Suspended Solids Associated with Dredging Operations on Estuarine Organisms," *IEEE Conference on Engineering in the Ocean Environment (Ocean '75 Record)*, Sep 1975, pp 431-436.

During dredging and disposal operations, there is an increase in the suspended solids in the area of activity. These resuspended sediments can adversely impact biota. The suspended solids concentrations during various dredging and disposal operations in San Francisco Bay were monitored. The results of this

monitoring were integrated with the results of a suspended solids test performed at the Bodega Marine Laboratory to develop a matrix of potential adverse effects on indigenous organisms under various suspended solids loadings. The matrix indicates that under winter condition of low temperature and high dissolved oxygen, adults of most species should not be adversely influenced during periods of either dredging or disposal. However, during summer months, if temperature increases to about 18°C and dissolved oxygen drops below two parts per million, mortality of sensitive species in the lower water column may result during disposal operations. The field investigations indicated that dredging could create a fluff zone at the sediment-water interface which because of its persistence might have adverse influence on benthic organisms.

Author's Abstract

Newcombe, C. L. and Pride, C. R., *Marsh Studies: The Establishment of Intertidal Marsh Plants on Dredge Material Substrate,* Feb 1975, San Francisco Bay Marine Research Center, Inc., Richmond, California.

In this study, cordgrass, *Spartina foliosa* Trin., and pickleweed, *Salicornia pacifica* Standl., were planted experimentally on intertidal dredged material substrate. Plant growth and environmental factors affecting survival and growth of the plants were measured. Nursery grown stocks of *Spartina* seedlings, robust rooted cuttings, and dwarf rooted cuttings, along with robust plug transplants, and seeds from natural areas of marsh were selected for study purposes. The *Salicornia* growth forms employed were nursery stocks of seedlings, rooted cuttings, and unrooted, vegetative cuttings.

In addition to controls, 66 experimental plots, half fertilized and half unfertilized, 5 by 5 m in size were planted in mid-May along with 14 transects of *Spartina* plugs and 4 transects planted with seeds of *Spartina foliosa* Trin. Records of survival and linear growth in the fertilized and unfertilized plots were made in mid-August and late October. The growth indices of size selected are: numbers of shoots, linear plant measurements, and weights of aerial and root parts of the plants. Attention was given to the extent to which volunteers of both species invaded the plots. Some records were made of growth of several plant forms taking place in the Point San Pablo Laboratory nursery of the Center. Also, records were taken of the man-hours effort required to pursue specific aspects of the work. Invasion of the fresh, unpopulated dredged material by benthic invertebrates was recorded in October. The environmental factors of the substrate that were measured include: moisture, substrate compressive strength, particle size of the sediment substrate, its chlorinity, alkalinity, total organic carbon content, nutrient content, redox potential, and ten chemical elements, all of which serve as indices of favorability of the soil environment for growth of marsh plants.

Because the oxidation-reduction potential of the dredged material may exercise a dominant effect on the germination of seeds and the growth of marsh plants, special attention was given to the redox potentials in the several environmental situations. Elevation is a dominant ecological factor limiting distribution and growth of intertidal organisms, hence, it was the subject of several intertidal transect studies of cordgrass plugs using robust and dwarf ecophenes. Morphological and anatomical descriptions of *Spartina foliosa* Trin. with emphases on the aerenchyma tissue for downward transport of oxygen to the root system were completed for the first time. The cytogenetic studies provided needed information on the chromosome composition of the robust and dwarf growth forms of *Spartina foliosa* Trin. Physiological laboratory experiments demonstrated the downward passage of oxygen transport from leaves to root systems of *Spartina foliosa* Trin. Data on volunteers that invaded the control plots are presented in an appendix along with much of the original growth data that is not contained elsewhere in this report.

U. S. Army Engineer District, San Francisco, CE, *Dredge Disposal Study, San Francisco Bay and Estuary; Appendix M, Dredging Technology,* Sep 1975, San Francisco, California.

A study was conducted under contract to the JBF Scientific Corp., Burlington, Massachusetts, to investigate dredging technology and to advance the state of knowledge regarding the short-term fate of dredged material dumped from barges or hopper dredges. Particular attention was given to application of the study findings to protection of the aquatic environment in the San Francisco Bay area.

Field tests evaluated physical and chemical properties of dredged material in many conditions, such as *in situ,* and in the pockets of a hopper dredge and a barge. Physical properties including moisture content and strength parameters were found to be quite variable within the pockets. Vibrations while vessels are under way had no significant effect on material properties, but heeling and swaying of the vessel appeared to have some slight influence in decreasing the moisture content in the lower portions of material in a hopper dredge.

Laboratory simulations of bottom dumping barges and hopper dredges were conducted with silt and clay sediments from San Francisco Bay navigation channels. These tests were performed in glass walled tanks and evaluated by means of motion pictures and still photography of the simulated dumping operations. Behavior of the dumped material as a function of sediment type (silt or clay), water type (fresh or salt), vessel configuration (hopper dredge or barge), water depth, sediment percent moisture, and dumped volume was studied. Parameters observed in characterizing the

data included descent velocity, cloud size, impact velocity, horizontal velocity following impact, and settling patterns. Moisture content appeared to be the primary variable determining behavior of dumped material.

Engineering aspects of intertidal disposal for the purpose of marsh creation were evaluated. Control of fill elevations was found to be enhanced by various means of predicting settlement and mechanical conditioning of deposited materials. Other considerations in marsh building were discussed, including tidal inlet design, means of excavating in marsh areas, and movement of salt through dredged material. This last subject, prompted by the desire to build marshes on abandoned salt evaporation ponds, was approached with a laboratory experiment. A lysimeter test was conducted to determine upward migration of sea salt through wet dredged material.

Certain aspects of land disposal were investigated with reference to conditions in the San Francisco Bay area. Treatment processes for removing contaminants and for hastening drying were discussed and evaluated. Productive uses of dredged material were also considered.

NOTE: The DMRP regrets it cannot be a distributing agent for the new items of literature listed in this newsletter. All items presented are available at the time of listing from the publishing or issuing agency and requests for copies should be addressed to them. In many instances, only limited copies are available and the use of Interlibrary Loan or related services is encouraged.

This bulletin is published in accordance with AR 310-2. It has been prepared and distributed as one of the information dissemination functions of the Environmental Effects Laboratory of the Waterways Experiment Station. It is principally intended to be a forum whereby information pertaining to and resulting from the Corps of Engineers' nationwide Dredged Material Research Program (DMRP) can be rapidly and widely disseminated to Corps District and Division offices as well as other Federal agencies, State agencies, universities, research institutes, corporations, and individuals. Contributions of notes, news, reviews, or any other types of information are solicited from all sources and will be considered for publication as long as they are relevant to the theme of the DMRP, i.e., to provide—through research—definitive information on the environmental impact of dredging and dredged material disposal operations and to develop technically satisfactory, environmentally compatible, and economically feasible dredging and disposal alternatives, including consideration of dredged material as a manageable resource. This bulletin will be issued on an irregular basis as dictated by the quantity and importance of information to be disseminated. Communications are welcomed and should be addressed to the Environmental Effects Laboratory, ATTN: R. T. Saucier, U. S. Army Engineer Waterways Experiment Station, P. O. Box 631, Vicksburg, Miss. 39180, or call AC 601, 636-3111, Ext. 3233.

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